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A model to estimate the probability of a strike on a point by a mid-latitude storm was developed and tested. This model was based on a vortex tracking program operational for quality control at the Fleet Numerical Oceanography Center, Monterey, CA. An extension of this model to assess the probability of a mid-latitude storm causing 30 kt winds also was developed and tested. Both developments followed successful comparable probability estimation models for tropical cyclones. Model development is described and the test methodology and results are described and interpreted.

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MID-LATITUDE WIND PROBABILITY MODEL

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1. Introduction

The concept of using probabilities to extend the useful life of storm forecasts was attempted nearly thirty years ago by Kimball (1958) and later Appleman (1962). Both used graphical means to estimate the probability of typhoon winds around U.S. Air Bases in the Far East. Practical use of probabilities began when Jarrell (1978) developed computerized methods to sum the tropical cyclone probabilities over time. The best known of these programs is the strike probability (STRIKP) which the Navy, Air Force and National Weather Service use to assess the likelihood of a tropical cyclone passing close enough to a base or city to cause major damage. Therein lies the definition of strike -- that the cyclone passed close enough to cause major damage. STRIKP is driven by point forecasts issued by a tropical cyclone warning center.

The idea of adapting the STRIKP model to provide comparable sophistication to the mid latitude forecasters has been hampered by the lack of centralized consistent point forecasts on mid latitude cyclones. However, point forecasts in a useable format became available with the development of the Quality Control Vortex Tracking Program (QCVTP) (see Tsui et al. 1982).

The purpose of this study is to demonstrate that the proven strike probability concept can be successfully operated using the QCVTP data bases. It should be noted that a statistical proof of the concept is not intended.

The concept of a mid-latitude wind probability model was formulated by SAIC under NEPRF contract No. N00228-84-C-3142. The need for a mid-latitude wind probability model is to aid ship captains and other decision makers in evading damaging winds from mid-latitude or extratropical cyclones. The cyclones are forecast but each forecast element (e.g., track, intensity and size) is subject to error. Wind probability helps allow for error by preventing overstimulation at points along the forecast track and understimulation at points off the track which are also significantly threatened.

The model accepts QCVTP type storm input data (low pressure center latitude, longitude, and pressure deficit, as well as the radius, ellipticity and angle of the major axis of the zero anomaly countour (ZAC)) at analysis time and up to 5 prognosis times (12-60 hrs). The output consists of strike and gale force wind probabilities in both instantaneous and elapsed time modes.

2. Strike Probability

The tropical cyclone working definition of a "strike" is that the cyclone passes within an area defined by semicircles of 75 and 50 n mi with the larger being on the left in the northern hemisphere (facing direction of motion). This allows for a greater extent of strong winds on the right side (see Jarrell and Brand, 1983). This definition appears inappropriate here since there is a large area of fairly light winds near the center of an extratropical cyclone and then the strong winds occur in a broad region often extending hundreds of miles from the center.

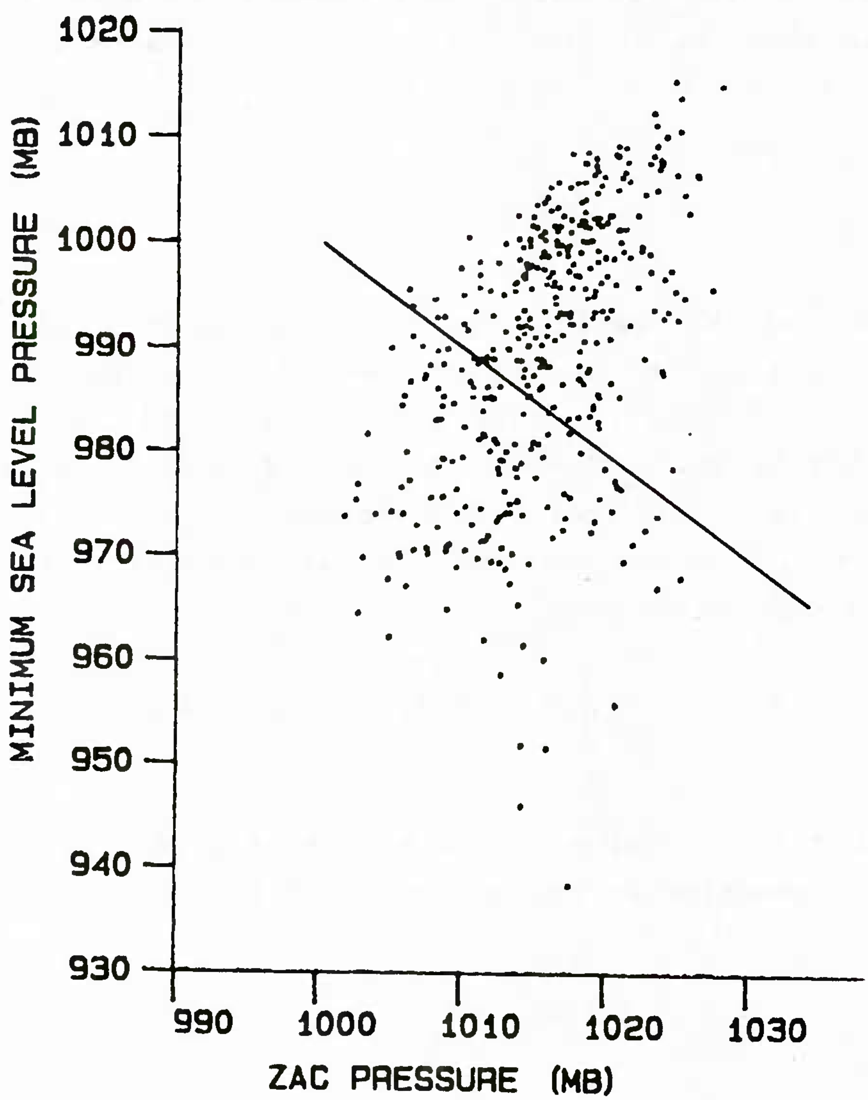

Figure 1. Scatter diagram of Oct-Dec 1984 North Pacific extratropical cyclones minimum sea level pressure vs pressure at the zero anomaly contour (ZAC). The line indicates the demarcation between strike area definitions using the 1000 isobar below the line and one half ZAC above the line.

It was first thought that perhaps a more reasonable definition would be entry into the area of depressed pressure, or within the zero anomaly contour (Tsui et al. 1982). This area is quite large--often 5 grid lengths and greater in radius (a grid length is 206 n mi at 60°N); consequently, being struck would then mean little more than being in an area of disturbed weather. The strike definition that was adopted is the storm passing close enough so the station falls within the 1000 mb isobar. For storms with a high central pressure so that the area within the 1000 mb isobar is small or nonexistent, this strike area is limited on the low side by half the radius of the zero anomaly contour (measured in grid lengths). The demarcation between the two definitions of the strike area is shown as a straight line in figure 1. Strike probability may therefore be defined as:

$$P_S = P(d \leq R_S)$$

where R_S is the strike radius; $R_S = KR_Z$, and R_Z=the ZAC radius. The multiplier K is defined as the maximum of [(central pressure - 1000)/(pressure deficit) or 0.5] and d is the passing distance. Now since both d and R_S are random variables (although both are forecast, there is uncertainty in their actual values) it is necessary to restate the above expression as:

$$P_S = \int P(R_S \geq r,\ d = r)dr = \int P(R_S \geq r \mid d = r)\ P(d = r)dr.$$

In this initial model the assumption is made that size errors are independent of position errors and hence that

$$P(R_s \geq r \mid d = r) = P(R_s \geq r).$$

Thus the expression to be integrated becomes:

$$P_s = \int P(R_s \geq r)\ P(d = r)dr$$

The expression $P(R_s \geq r)$ was evaluated by creating a probability contingency table of the radius of the ZAC observed (in the QCVTP data) versus that forecast (see Table 1). The probability term evaluated by the use of a contingency table is being estimated on the basis of climatological experience. This could have been accomplished by parameterizing the distribution; however, from the standpoints of sample size and convenience of computation the contingency table is preferable. Thus the first expression $P(R_s \geq r)$ can be viewed as $P(R_s \geq r \mid R_f)\ P(R_f)$ where $P(R_f)$ is the probability of forecast R_f being made; $P(R_f) = 1.0$, since the forecast is known. Table values are given for $r = \leq 2.5, 2.5\text{-}3.0, 3.0\text{-}3.5 \ \ldots > 5.5$ in multiples of grid lengths. Since r takes on these discrete values, the above integral is treated as a summation and the term $P(d = r)$ is evaluated as the

$$P(r - .25 < d \leq r + .25)$$

which is a ring about the point of interest of width one half grid length. This term is position dependent. Required is the probability that the storm center falls within concentric rings about <u>the point of interest</u>. If the rings were centered on the storm forecast, then a contingency table approach could again be used at considerable savings in program complexity and execution time. The most reasonable way to evaluate this term is by fitting a parametric distribution to historical forecast errors. The distribution is then inte-

grated over rings with a variable center location relative to the distribution center. A bivariate normal distribution has typically been used to fit such errors because it has characteristics which match those of the error population (positively and negatively unbounded with a central tendency in two components). See Crutcher et al, 1982 for a discussion of this distribution and forecast errors. The goodness of fit has not been determined in this case.

Table 1. The probability of a particular mean ZAC radius being exceeded in the verifying analysis given the twenty-four hour forecast. Similar tables are used for other forecast intervals. The column under the 0.0 grid lengths heading would be 100% except for dying storms whose frequency is shown under the column NONE.

24-HOUR TABLE OF EXCEEDANCE PROBABILITIES OF R

FORECAST	0.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	NONE	SAMPLE
<2.5	72.	19.	10.	7.	3.	0.	0.	0.	28.	89
2.5-3.0	78.	51.	22.	7.	3.	0.	0.	0.	22.	68
3.0-3.5	90.	80.	59.	26.	13.	3.	1.	0.	10.	93
3.5-4.0	89.	85.	70.	51.	22.	6.	3.	1.	11.	94
4.0-4.5	86.	85.	77.	68.	41.	14.	5.	1.	14.	73
4.5-5.0	85.	82.	78.	72.	51.	29.	12.	3.	15.	68
5.0-5.5	88.	84.	77.	74.	67.	53.	28.	12.	12.	43
>5.5	89.	87.	87.	80.	71.	64.	50.	36.	11.	70

Time integration is handled just as it is in the tropical programs except for the following:

a. Given the tropical input from warnings, all forecast sequences run from tau = 0 to some last tau, usually 72 hours. With mid-latitude cyclones, the low frequently appears first on a prog chart.

b. Points are frequently threatened by more than one low center over the 60 hour period of integration.

Probabilities from different storms are summed as if independent.

$$P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$$
$$\text{and } P(A \text{ and } B) = P(A)P(B)$$

c. All time integrated probabilities are given for the entire 60 hour period. Exception (a) (above) causes probabilities to suddenly appear on a time line whereas exception (b) causes humps on the time line unlike the smooth increase to a peak then a decrease over time as seen in the tropical probability curve.

Sample strike probabilities are shown in figure 2.

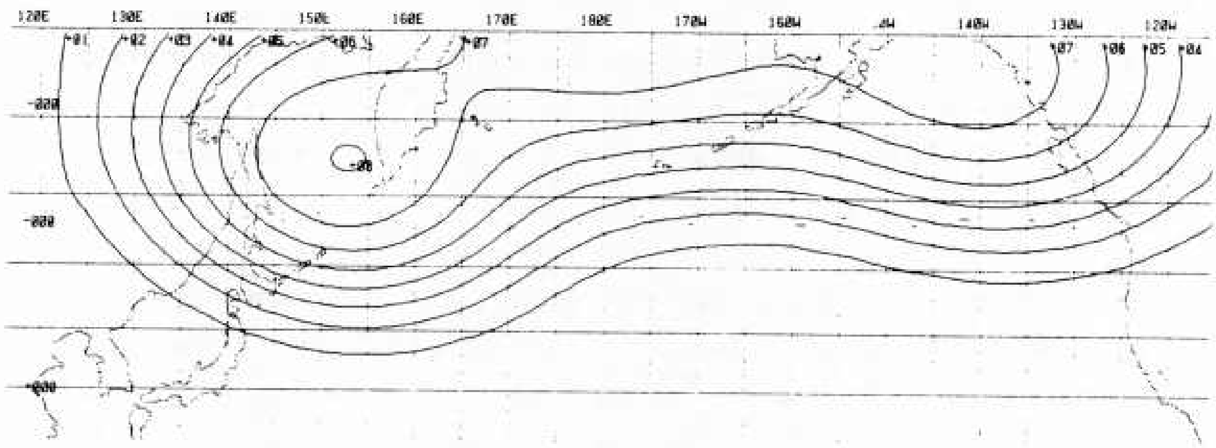

Figure 2a. Strike probability (units are tens of %)

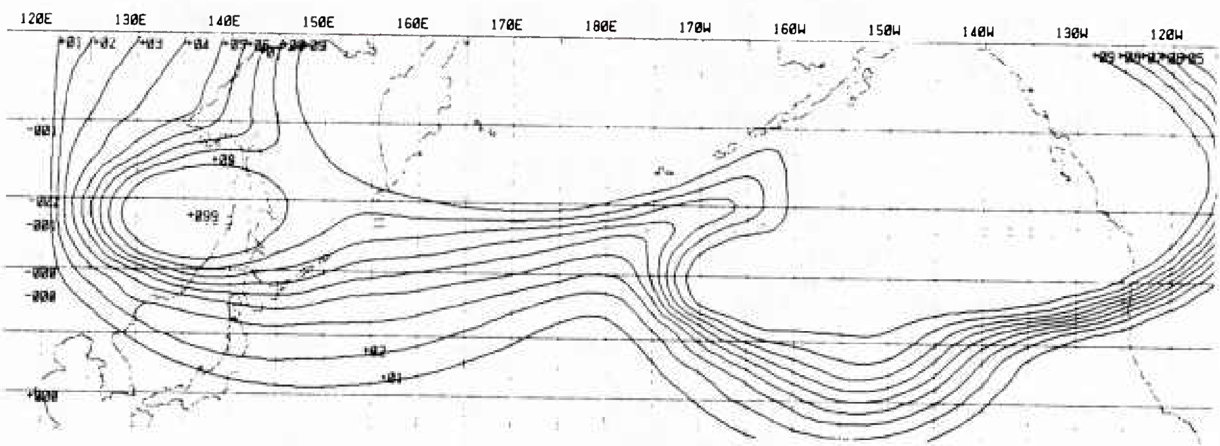

Figure 2b. Elapsed time strike probability (units are tens of %).

Figure 2. 24-hour probability forecast for 1200 GMT 8 November 1984, North Pacific Ocean.

3. Wind Probability Model

The wind probability model is designed to produce the probability of gale force winds ($\geq$28 kt) although provision was retained to include one other wind speed (e.g., storm force or 48 kt). Both instantaneous and elapsed time wind probabilities will be provided in the same format as strike probabilities.

The form of the wind probability is

$$\int P(V_o > 28 | x,y)\ P(x,y)\ dxdy$$

where V_o = the wind speed at point x_o,y_o, the point of interest; x,y is the location of the storm center. Clearly $P(V_o > 28| x,y)$ is highly dependent on the location of point x_o,y_o relative to point x,y. What is needed is a model to relate the wind probability to locations. The relationship of wind to location relative to the storm center is a function of storm size, pressure depth, the shape of the pressure profile and the assymetry of the storm.

In an analysis mode these parameters can be measured and converted to good wind estimates by use of the gradient or geostrophic wind equations. This also applies to the prognostic mode except that the various parameters are of unknown accuracy; hence the forecast winds are of unknown value. In a probabilistic mode one wants to find the sets of parameters which produce winds of interest, for example, over 28 kt or gale force winds. The joint probability of these sets occurring would then be estimated. The more variables (e.g., size, minimum pressure, profile shape, as well as direction and distance of the point of interest from the storm)

involved in each alogrithm the more complex the problem. Also additional variables cause additional stratification of the available data base; thus the size of the data base in effect limits the complexity of the joint probability solution.

In the tropical models, the wind field was assumed to be totally defined by three parameters, maximum wind, a scaling radius and forward speed. Forward speed had a rather minor role and was assumed to be perfectly forecast. This left only two parameters to describe the wind field. Their joint probability, given the forecast, was readily determined from climatological forecast data.

There are no similar models for extratropical cyclones. It is assumed here that the assymetric radial profile of winds is a function of the maximum pressure gradient and orientation of the major ellipse axis. The maximum pressure gradient (in a mean sense) can be computed by the pressure differential divided by the length of the minor axis. Consequently storms were classed by maximum gradient vs angle of orientation of the major axis.

The distribution of these classes is shown in the scatter diagram of Figure 3. Presumably storms with the strongest mean gradient have the strongest winds. Next contingency tables of forecast classes versus observed classes were computed; thus the probability of a particular class occurring, given a forecast, could now be estimated (see Table 2). The spatial distribution of winds was now derived separately for each storm class.

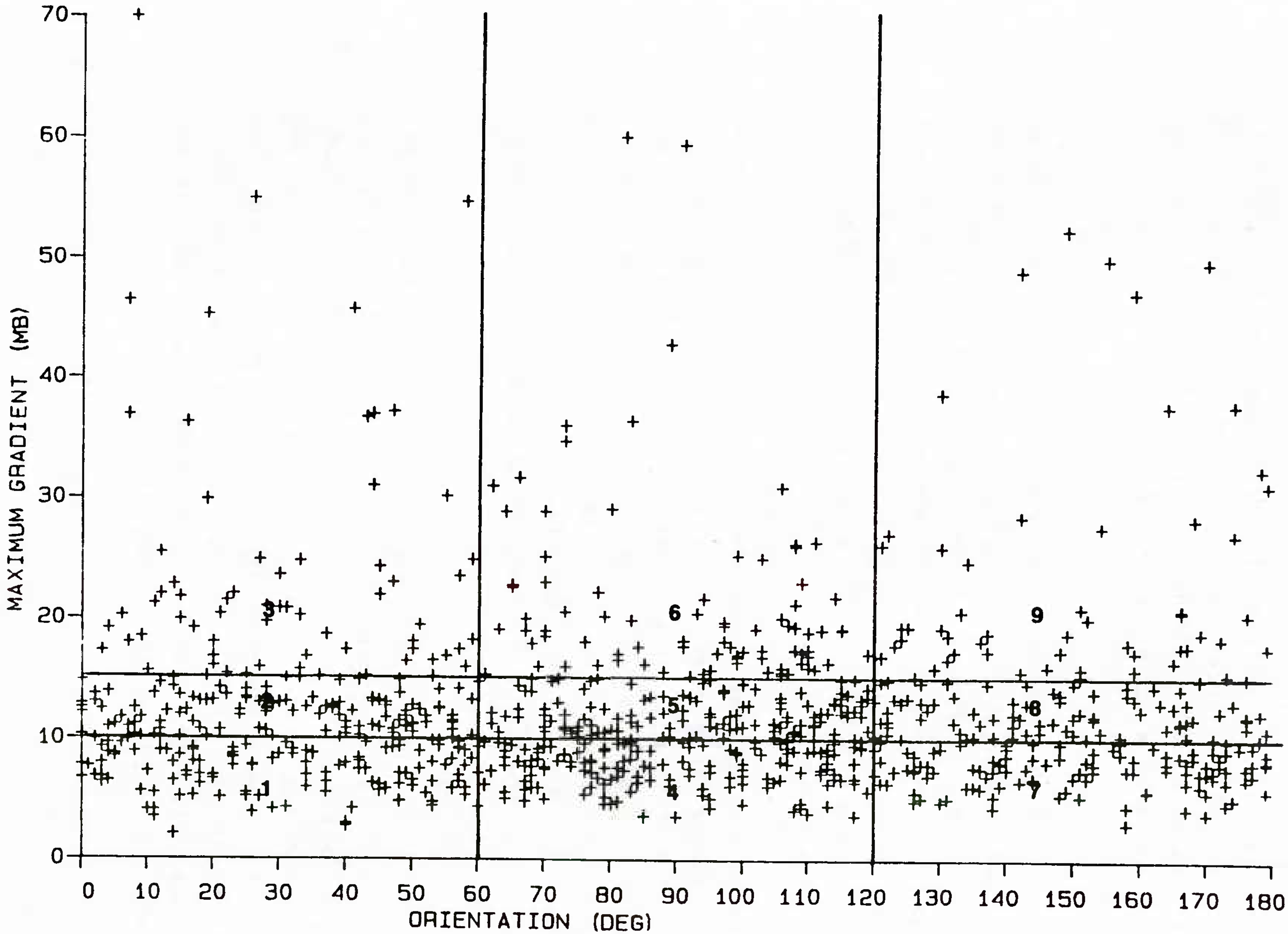

Figure 3. Scatter diagram of October 1984 - April 1985 North Pacific extratropical cyclones maximum pressure gradient (mb per grid length) vs orientation of major axis (deg). A preliminary classification based on maximum gradient vs orientation is shown.

Table 2. The probability of a storm becoming a member of each size-depth class after 24 hours given its particular forecast class. Percentages left to right in a row would add to 100% except for dying storms.

24-HOUR CLASS CONTINGENCY TABLE

OBSERVED CLASS

FCST CLASS	1	2	3	4	5	6	7	8	9	SAMPLE SIZE
1	22.	19.	6.	10.	8.	4.	11.	5.	1.	79
2	9.	40.	13.	6.	11.	4.	4.	4.	4.	53
3	3.	26.	37.	3.	3.	0.	5.	3.	5.	38
4	7.	7.	4.	26.	14.	4.	11.	8.	1.	114
5	2.	5.	3.	11.	32.	18.	5.	1.	2.	87
6	3.	2.	8.	12.	10.	31.	0.	2.	5.	59
7	9.	3.	2.	12.	8.	0.	26.	20.	3.	65
8	3.	12.	1.	7.	12.	6.	7.	19.	15.	68
9	2.	7.	9.	2.	4.	7.	9.	22.	24.	46

The approach was to compute winds on a grid centered on the cyclone. This is a special symmetrical grid with concentric circles of grid points increasing in number outward so that all grid spaces contain equal areas (see Figure 4). Stored at grid points for each class storm is the probability that gale force winds would be observed at the center or grid space #1 if a storm (of the given class) were located in the grid space in question (see Figure 5). Assymmetry is considered at the expense of a somewhat complex model since there are now 71 grid points for each integration step. However, because the grid spaces are equi-area, the computation of the probability of the storm occupying a grid space is simplified.

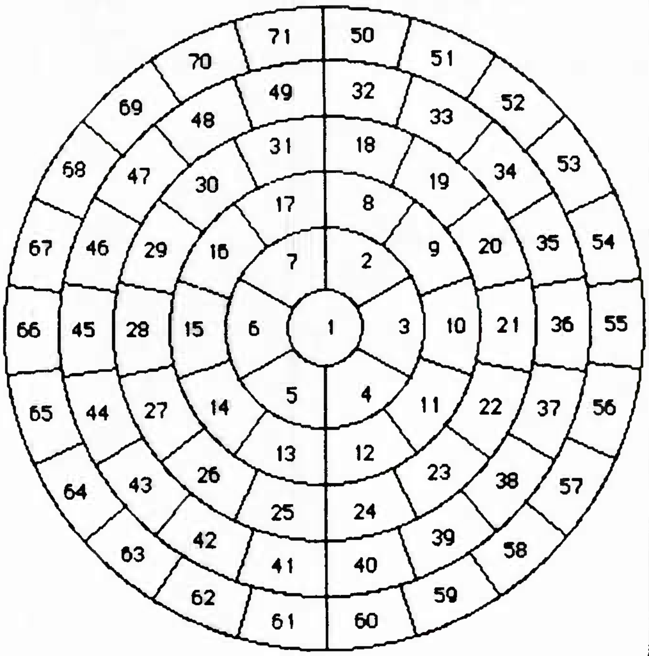

Figure 4. Equiarea grid which was placed over moving cyclone to extract wind speeds for evaluation of conditional wind probabilities. The radius of the central circle is about 85 n mi and the outer circle 720 n mi. Numbers are grid identifying numbers.

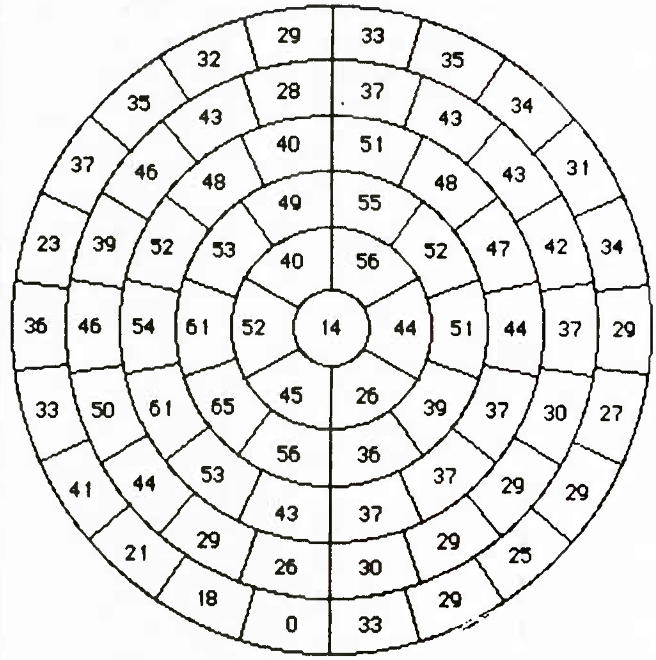

Figure 5. Grid of gale force wind probabilities for class three (N-NE and strong) cyclones given in whole percent. This is based only on October 1984 - April 1985 data.

With this grid oriented model the operative wind probability expression becomes:

$$P(V \geq V_g, c=K,\ g=L|\ c=K|\ g=L)\ P(g=L|\ \text{forecast}\ x,y)\ P(c=K|\ \text{forecast})$$

where the first product term is the probability that the wind equals or exceeds gale force given that a storm of class = K is located in grid space L. The second product term is the probability that a storm occupies grid space L given the forecast for this time x,y. The last term is the probability that the storm is of class K given the forecast class. An assumption of independence between the last two terms is implicit.

The resulting probabilities are reasonable in appearance. Sample 24-hour wind probabilities are shown in figure 6.

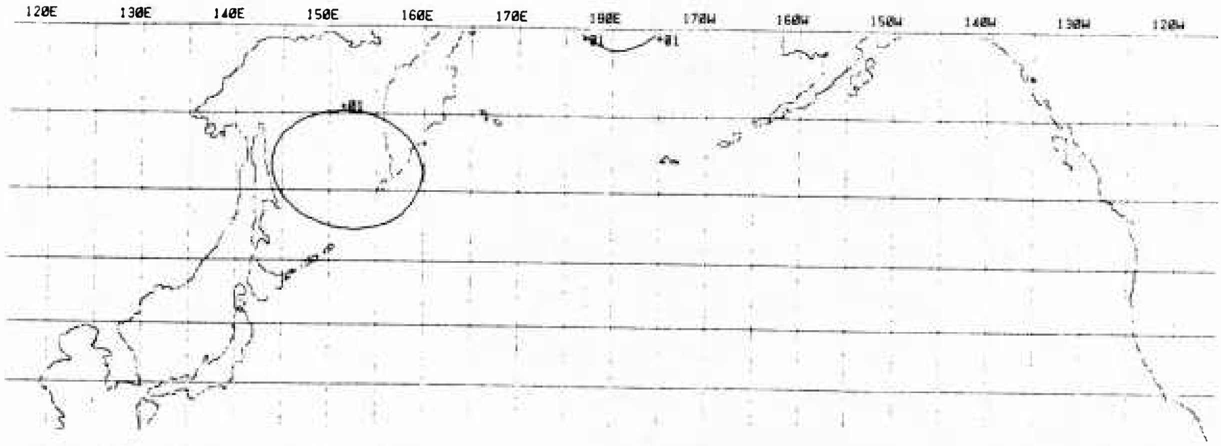

Figure 6a. Gale force wind probability (units are tens of %).

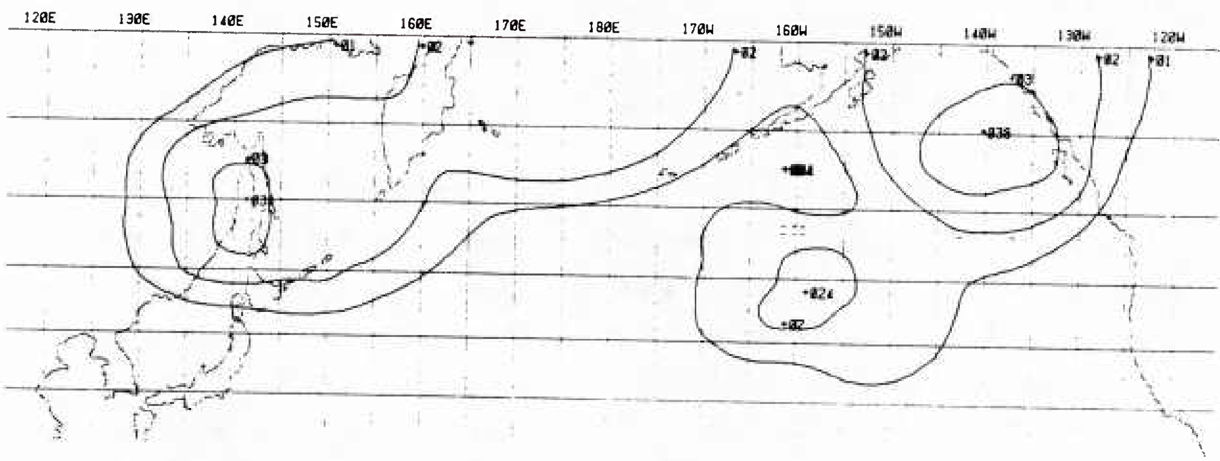

Figure 6b. Elapsed time gale force wind probability (units are tens of %).

Figure 6. 24-hour wind probability forecast for 1200 GMT 8 November 1984, North Pacific Ocean.

4. Independent Testing

An independent data set of FNOC analysis and prognosis surface pressure fields was obtained for December 1983 through March 1984. Forecast intervals were from 12 to 48 hours by 12 hour increments. The QCVTP program was run on these fields for the North Pacific Ocean, providing the basis for the strike and wind probability computation. To maintain approximate serial independence between fields, every third 12 hourly date-time-group was selected for probability computations. In all, 56 date-time groups were chosen which involved 99 different cyclones which appeared in an average of 2.2 prognosis series each (there are 244 12 hourly fields in the December-March period: however, several fields were missing).

4.1 Verification Data

Since probabilities would be computed on prognosis series of 48 hours long initiated every 36 hours, all analyses would be used as verification data (except for the first few). For the purpose of strike verification, each cyclone was examined against each grid point over the Pacific sector of the FNOC 63x63 northern hemisphere grid. A strike was considered to have occurred if the grid point fell within an elliptical strike area surrounding the cyclone. This strike area was defined as an ellipse approximating the 1000mb contour or within 1/2 the distance out to the zero anomaly contour, which ever was greater. A file was created showing which grid points had been struck for each available analysis date-time-group. Gale force winds were verified in much the same way except that geostrophic winds were calculated at

grid points. When 80% of the geostrophic wind exceeded gale force (28kt) it was considered that gale force winds had been observed at the grid point. The factor of 80% is used to compensate for the fact that geostrophic winds generally over estimate actual surface winds and particularly so around cyclones. As with strikes, a file was created showing which grid points had received gale force winds.

With the strike and wind verification data in place, each selected date-time was processed by computing strike and wind probabilities for each grid point. These were then categorized into 5% cells and a running sum of the probabilities, the verification (0 if not struck, 1 if struck and similiar for winds) and case count were maintained for each cell. Comparisons were made of the expected occurrence of strikes or gale force winds versus the observed occurrences.

4.2 Test Results

Figures 7 through 10 show the results of these comparisons. The straight line from lower left to upper right represents the expected frequency of occurrence. The asterisk represents the actual frequency of occurrence. The vertical I-beam represents 99% confidence limits around the expected frequencies based on a "t" test. Visually the agreement between observed strike frequencies and expected strike frequencies is quite good. However, it should be noted that far too many (much more than 1%) of the observed values fall outside the 99% confidence limits. The visual

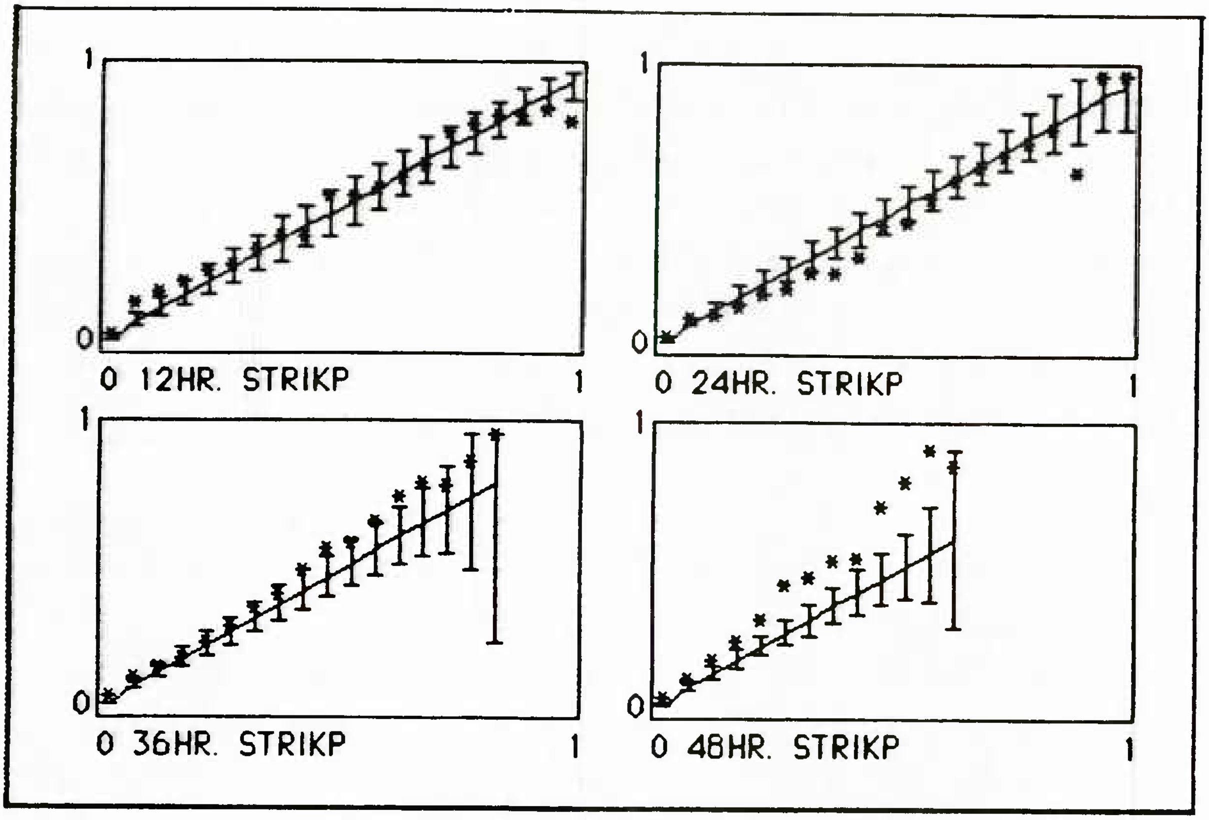

Figure 7. Comparison of expected (diagonal line) vs the actual (*) strike frequencies. I-beams represent 99% confidence limits (t-test) about the expected frequency. Both the ordinate and abscissa are frequencies (0 to 1).

fit confirms that the strike probability is a good estimate of the actual strike frequency, while the excessive number of cases falling outside the 99% confidence limits points out that there are limitations on the applicability of at least some of the model assumptions. For example, in the instantaneous mode there is apparently a tendency to underestimate strike probabilitites. This can be attributed to better FNOC model forecasting in the independent cases than in the development sample. It would not be surprising that such changes would occur either because the models change (note the independent set predates by one year the development set) or

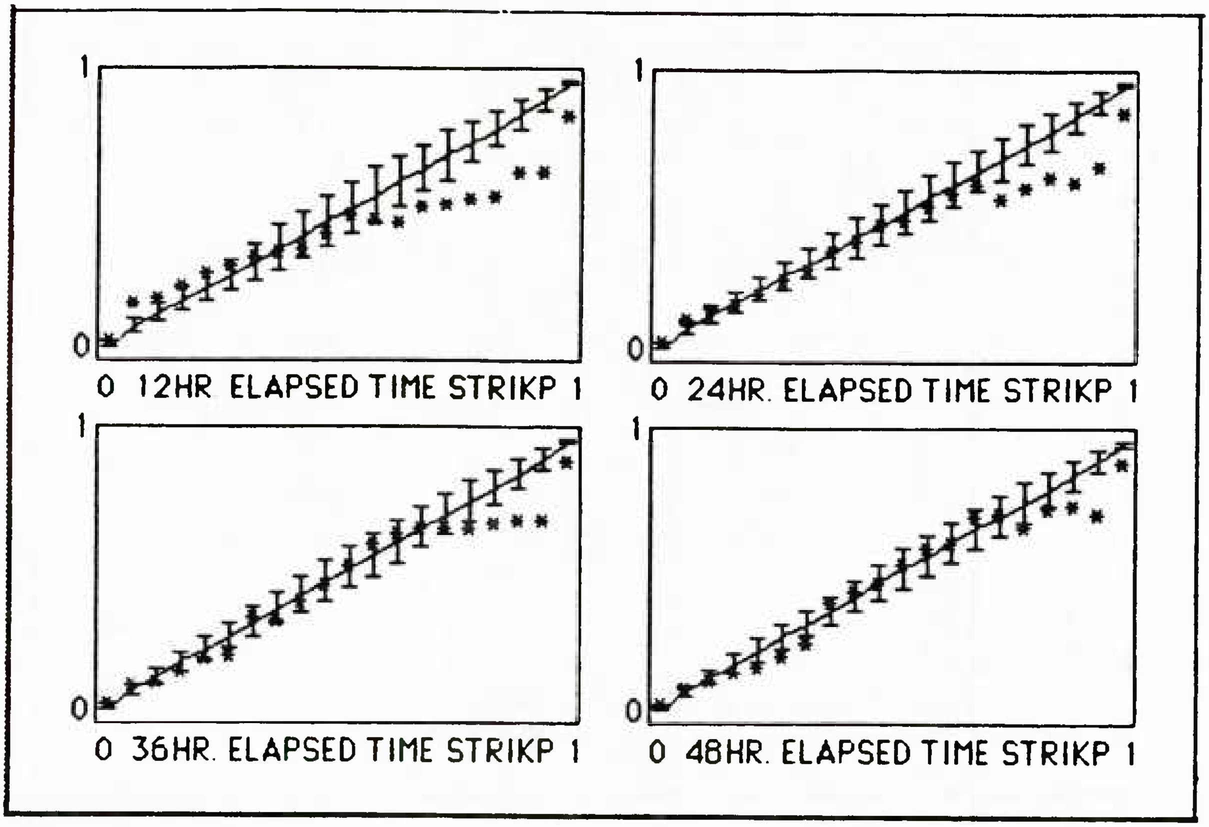

Figure 8. Comparison of expected (diagonal line) vs the actual (*) elapsed time strike frequencies. I-beams represent 99% confidence limits (t-test) about the expected frequency. Both the ordinate and abscissa are frequencies (0 to 1).

simply due to a natural difference in the two rather limited data sets. Notice that in the elapsed-time-strike-probabilities there is a tendency to significantly overestimate probabilities which runs counter to the previously mentioned problem and consequently the agreement between expected and observed improves over time. Overestimation in the summation process is caused by a faulty parameterization of the independence of strikes in consecutive time steps. This would be an overestimate of independence perhaps because large time steps allow substantial storm movement between probability computations.

The comparison for gale force winds is a different story (see figures 9 and 10). Visually it is apparent that there is little predictive skill in the wind probabilities except at

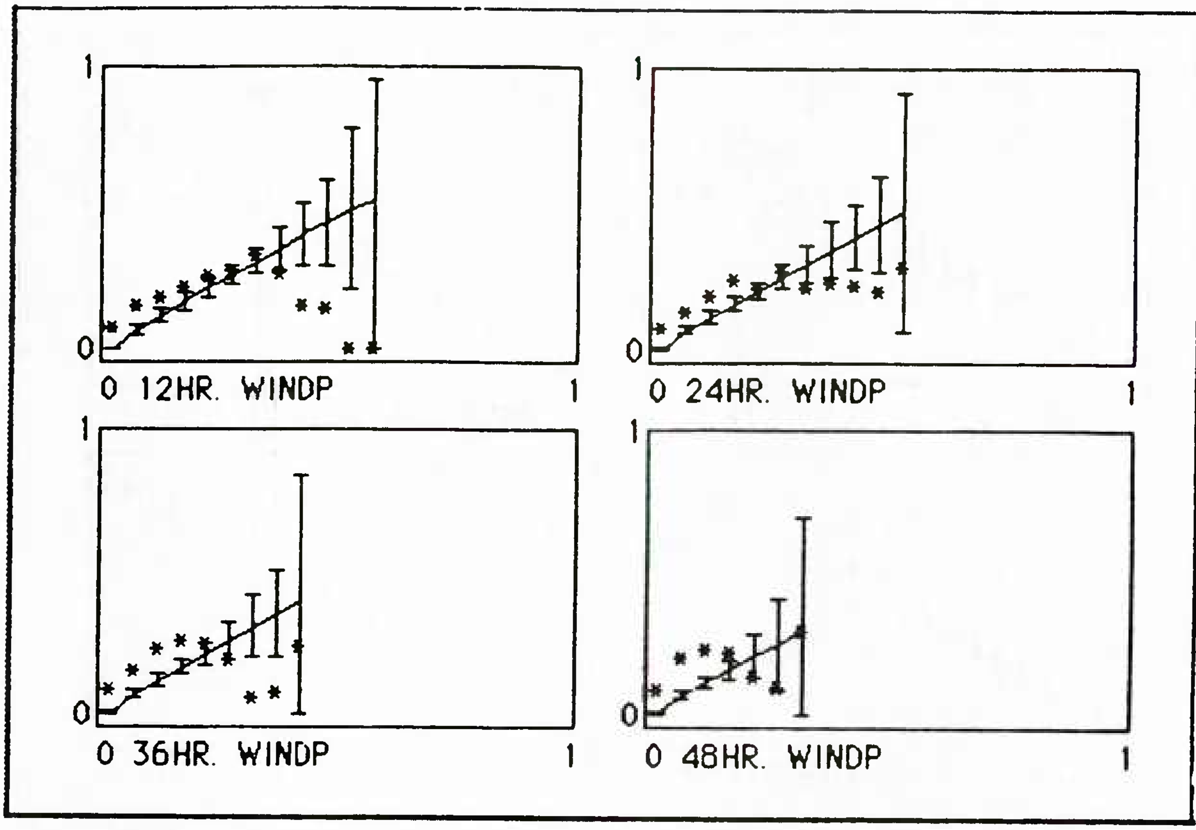

Figure 9. Comparison of expected (diagonal line) vs the actual (*) gale force wind frequencies. I-beams represent 99% confidence limits (t-test) about the expected frequency. Both the ordinate and abscissa are frequencies (0 to 1).

low probability levels and even then they are biased on the low side. It is not likely that this poor agreement can be attributed to one cause, but the lack of a good model of the spatial distribution of winds around extratropical cyclones is doubtless a major contributing factor. QCVTP by its methodology of fitting ellipses to low pressure aras is not a good estimator of wind fields. The low side bias may be attributable to using 80% of the geostrophic wind for verification and indeed using 75% of that wind essentially elimates that bias, but of course the agreement with the high probabilities in comparably aggravated since they are generally over forecast. One of the problems which plagues the wind probabilities is that there tends to be a very large central

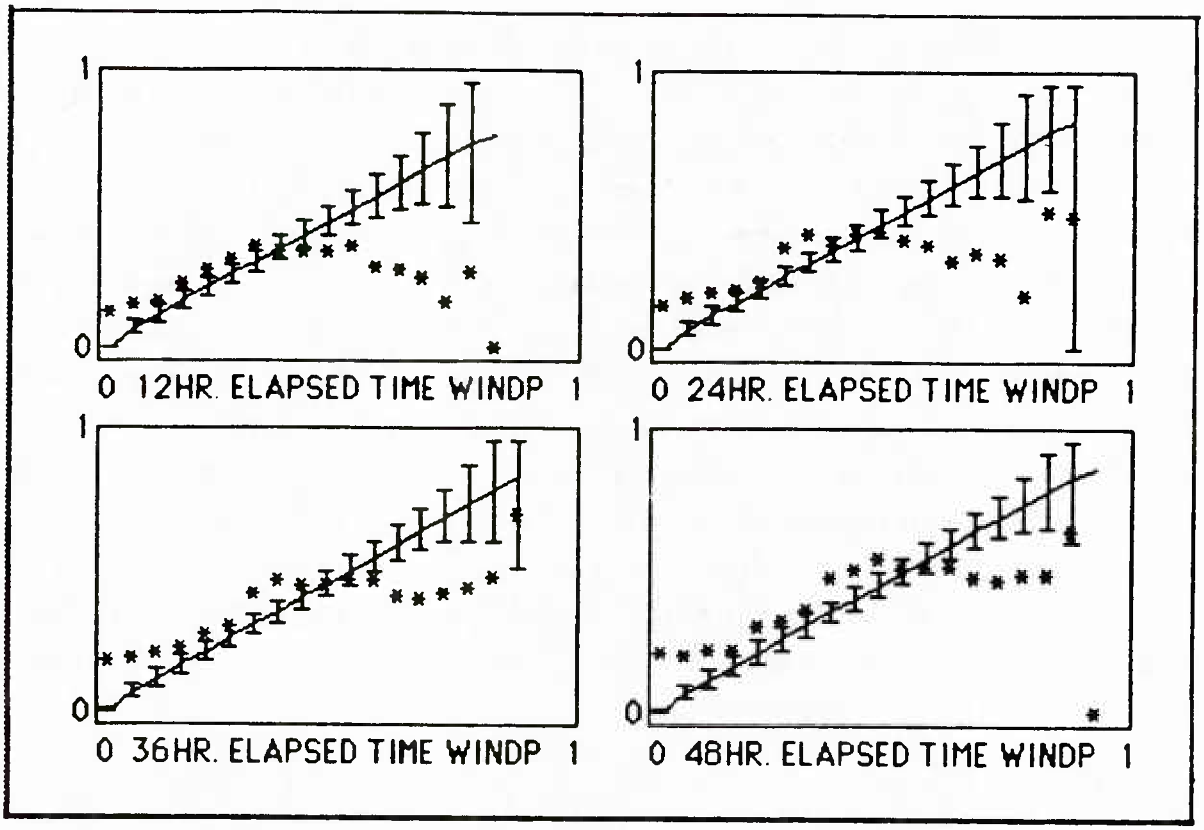

Figure 10. Comparison of expected (diagonal line) vs the actual (*) elapsed time gale force wind frequencies. I-beams represent 99% confidence limits (t-test) about the expected frequency. Both the ordinate and abscissa are frequencies (0 to 1).

area within an extratropical cyclone which is characterized by light winds. For this reason very high strike probabilities are associated with light winds. These also tend to be associated with high wind probabilities as can be seen in figures 9 and 10.

5. Summary and Recommendations

A realistic model has been developed and tested for mid-latitude strike probabilities. A comparable model for wind probabilities proved to be much less reliable and not usable. The definition of strike does not necessarily imply severe weather from the standpoint of naval operations, but it does imply that one of the necessary conditions required for severe weather, the presence of a cyclonic storm, has been met. With subjective screening of the severity of a storm, STRIKP can be used as an early warning precursor of severe weather -- perhaps the basis of a storm or gale condition III or IV (gales are possible within 48 or 72 hours respectively). Similarly, for ship routing, a high strike probability may not be suitable justification for definitive evasive actions but rather to position oneself favorably for evasion should it be warranted later.

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APPENDIX A
USER'S MANUAL FOR PROGRAM WNPPSG

1.0 Introduction

The Pacific mid-latitude strike and wind probablilty model was developed by SAIC under NEPRF contract No. N00228-84-C-3142. The reason for developing a mid-latitude cyclone probability model is to aid ship's captains and other decision makers in evading dangerous conditions in mid-latitude or extratropical cyclones. Track, intensity, and size of these cyclones are forecast, but each forecast element is subject to error. Probablity helps allow for error by preventing overstimulation at points along the forecast track and understimulation at points off the track which are also significantly threatened.

The model accepts SEIS output storm data ,(low pressure center latitude, longitude, pressure deficit, as well as the radius, ellipticity and angle of the major axis of the zero anamoly countour (ZAC)) at analysis time and up to 5 prognosis times (12-60 hrs), as input. The output consists of strike and gale force wind probabilities in both instantaneous and time elapsed modes.

2.0 Program Operation

The Model software is called WNPPSG (WiNd Probability, Polar Sterographic Grid). WNPPSG accepts real time output from the SEIS program as input. The files from SEIS are: ANSTRM, FCSTRM, and QCDATE. QCDATE is the current date on which SEIS was run. ANSTRM is in Update format and is updated by the JCL.. ANSTRM consists of low pressure center latitude, longitude, and pressure deficit, as well as the radius, ellipticity and angle of the major axis of the zero anamoly countour (ZAC) at analysis time and up to 5 prognosis times (12 - 60 hrs). FCSTRM consists of the same parameters of storms that are forecast to occur but which have not yet been observed.

WNPPSG also reads files PDLTR and CLSTAT. PDLTR is a file of bivariate normal probabilities and CLSTAT is a file of climatological statistics on the frequency of occurrence of storms of various radii and of storm classes based on orientation versus maximum pressure gradient.

Output is a series of plots of strike and gale force wind probabilities in both instantaneous and time elapsed modes.

The Technical aspects of this program are described in the final report for Contract N00228-84-C-3142.

The following are some examples of the real time input files used by WNPPSG.

File Anstrm:

```
  292   219    32     0     0     0     0     0   157   248   158   223
  205   170    27     0     0     0     0     0   136   180   125   169
  205   161    19     0     0     0     0     0   138   178   113   160
  215   167    16     0     0     0     0     0   125   163   118   172
  222   175    11     0     0     0     0     0   128   183   116   180
  211   178    11     0     0     0     0     0   122   184   133   179
  217   172    11     0     0     0     0     0   112   180   135   175
  110    90     6     0     0     0     0     0    49    81    65    92
  112   103     6     0     0     0     0     0    55    80    69    79
  120    83     6     0     0     0     0     0    55    85    61    70
  114    86    11     0     0     0     0     0    58    81    64    89
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0
860228122140 86022700 36 11005105120111206404-13  94  -1  173   14
860228122140 86022700 48 1 997 34100117200400-19 121  14  208   30
860228122140 86022700 60 1 991 14 74173191389-26 139  25  233   43
860228122140 86022700 72 1 985 10 67 42184376-31 137  31  235   50
860228122140 86022700 84 1 983 26 93 45177360-3399999999  226   52
860228122140 86022700 96 1 982 32 93 44173347-34 125  23  218   48
860228122140 86022700108 1 984 41114 76171336-3299999999  220   43
860228122140 86022700120 1 986 42120 84170305-30 146  21  218   45

860302122138 86022700 84 1 994 43 30 62214380-2399999999  133   42
860302122138 86022700 96 1 993 91 78155210377-22  72  11  124   32
860302122138 86022700108 1 992 30 51163201372-2199999999  137   18

860304002426 86022800 96 1 988 26 31116240260-19  28  57   59   96
860304002426 86022800108 1 992 36 27 99245258-1399999999   72   81

860302001729 86030112 12 1 991 29 94 75172288-25  79  10  151   14
860302001729 86030112 24 1 989 13 71 84180265-24  66  34  121   55
860302001729 86030112 36 1 984 15 62 67187259-28  53  51   96   78
860302001729 86030112 48 1 979 11 48149197260-35  33  73   64  103
860302001729 86030112 60 1 977 18 49174201264-36  25  76   51  107
860302001729 86030112 72 1 981 43 48  5205270-32  11  73   31  107
```

Figure 1. A segment of the File ANSTRM, 16 storms have been omitted.

File FCSTRM:

```
*DECK MISFORCST
   0    0    0    0    0    0    0    0    0    0    0    0
   8   18    0    0    0    0    0    0    2    5    2    9
  23   25    0    0    0    0    0    0    7    5    6   14
  45   40    1    0    0    0    0    0    8   10    9   21
  55   53    0    0    0    0    0    0   11   58    9   30
  62   67    0    0    0    0    0    0   12   67   22   39
  75   75    0    0    0    0    0    0   16   69   31   36
  47   47    0    0    0    0    0    0    9   29   18   17
  56   62    0    0    0    0    0    0   11   81   21   17
  63   50    0    0    0    0    0    0   13  147   24   16
  67   59    0    0    0    0    0    0   18  104   25   27
   0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0
*DECK P86C81826
860302001826 86030200 00 1 985 24 65 83178261-29  68  47  118   74
860302001826 86030200 12 1 989 14 50 78186263-25  43  61   88   92
860302001826 86030200 24 1 985 14 53121188268-28  33  58   71   83
860302001826 86030200 36 1 982 16 57148192270-32  24  61   56   84
860302001826 86030200 48 1 982 40 59172196271-33  12  64   41   93
860302001826 86030212 00 1 984 16 59 96188261-29  37  59   72   91
860302001826 86030212 12 1 985 17 58131189267-28  42  66   76   93
860302001826 86030212 24 1 982 16 49169196268-32  21  77   54  102
860302001826 86030300 00 1 983 26 63134193269-31  36  64   68   89
860302001826 86030300 12 1 986 56 62163196267-29  37  82   66  110
860302001826 86030312 00 1 990 22 39179211261-23  27  90   64  120
860302001826 86030312 12 1 996 10 26 32228267-15  22  73   62  101
860302001826 86030400 00 11000 14 24 65230270-10  18  61   62   83
*DECK P86081943
860302121943 86030212 00 11002 19 59162190426-14 187  26  329   66
860302121943 86030212 12 1 997 36 61 21182403-18 178  24  310   56
860302121943 86030212 24 1 991 15 71 33177388-23 167  17  278   50
860302121943 86030212 36 1 991 18 89 74168369-26 153   0  255   23
860302121943 86030300 00 1 993 35 81 48183395-23 170  20  296   57
860302121943 86030300 12 1 990 17 79 97179388-26 154  24  274   60
860302121943 86030300 24 1 988 19 90 72172371-27 147   8  249   30
860302121943 86030312 00 1 992 16 84 78177379-24 149  14  263   54
860302121943 86030312 12 1 988 27111 65170353-29 128  -6  224   14
860302121943 86030400 00 1 975 22 83 44173358-41 118  -2  213   18
860302121943 86030400 12 1 980 27120 72164341-36 129  -9  221    5
860302121943 86030400 24 1 977 27120 84161320-37 132   3  208   18
```

Figure 2. A segment of the File FCSTRM, 2 storms have been omitted.

JCL for the Program WNPPSG.

```
xxxxl,STSPC,SJ,P3,EC150.  WNPPSG
ATTACH,QCPAC,ID=XJ.
ULIB(QCPAC,ANSTRM,FCSTRM,QCDATE)
RETURN,QCPAC.
UPDATE,F,D,L=0,C=0,I=EMPTY,P=ANSTRM,S=TAPE3.
REWIND,FCSTRM.
COPY,FCSTRM,TAPE4.
ATTACH,CLSTAT,ID=JL.
REWIND,CLSTAT.
COPY,CLSTAT,TAPE5.
RETURN,CLSTAT.
ATTACH,PDLTR,ID=JL.
REWIND,PDLTR.
COPY,PDLTR,TAPE6.
RETURN,PDLTR.
REWIND,QCDATE.
COPY,QCDATE,TAPE8.
RETURN,ANSTRM,FCSTRM,QCDATE.
LIBRARY,*FNWCLIB.
MAP,ON.
FTN,R=2.
LGO.
MAP,OFF.
LIBRARY(*FNWCOVL)
ROUTE,PLOT,DC=PV,FID=xxxx,TID=C,BIN=xx,DEF,CO=xxxxxx.
ONSW,6.
VARITNY.
*EOR
```

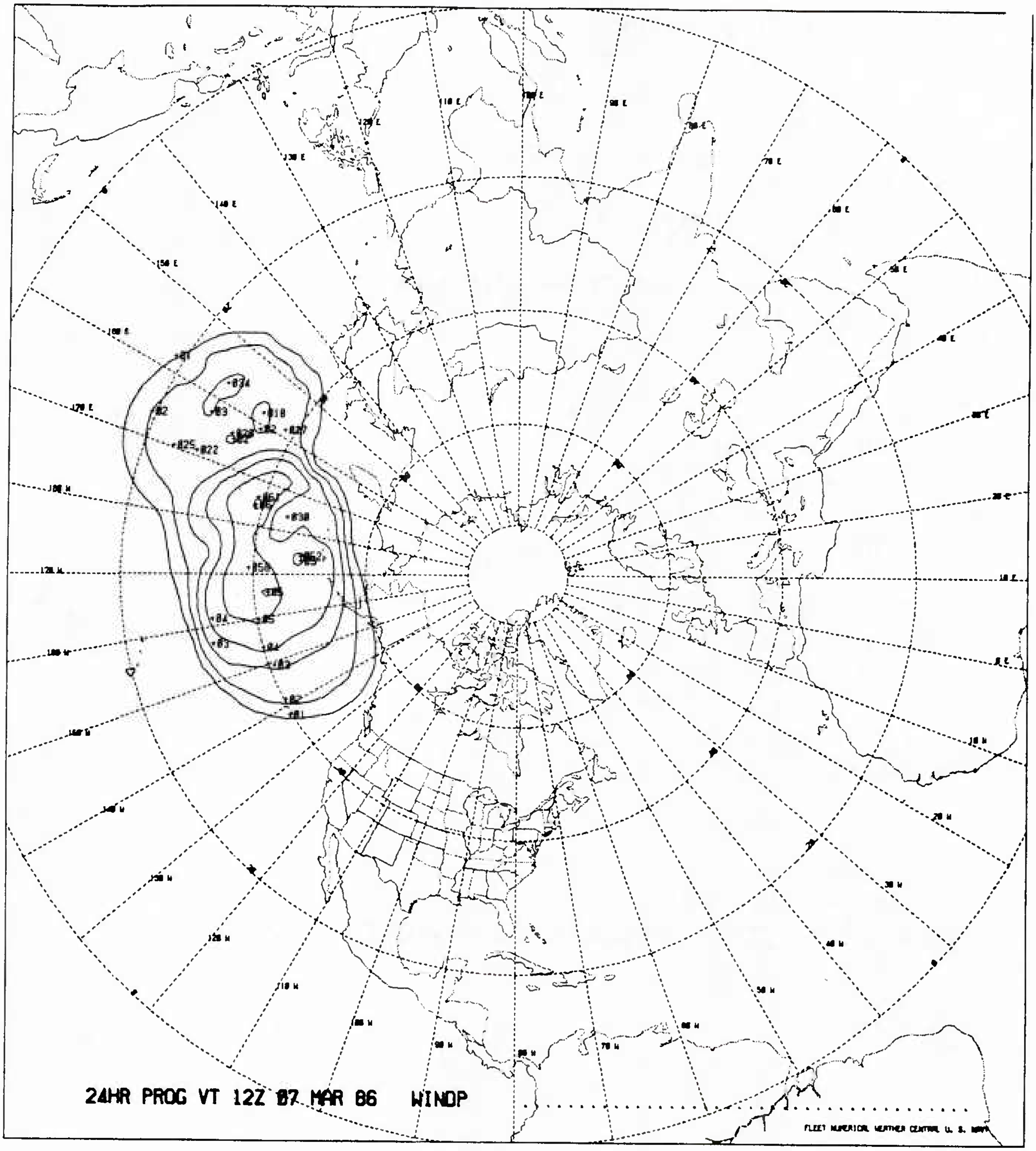

Figure 3. 24 Hour Elapsed Time Gale Force Wind Probability for the Pacific.

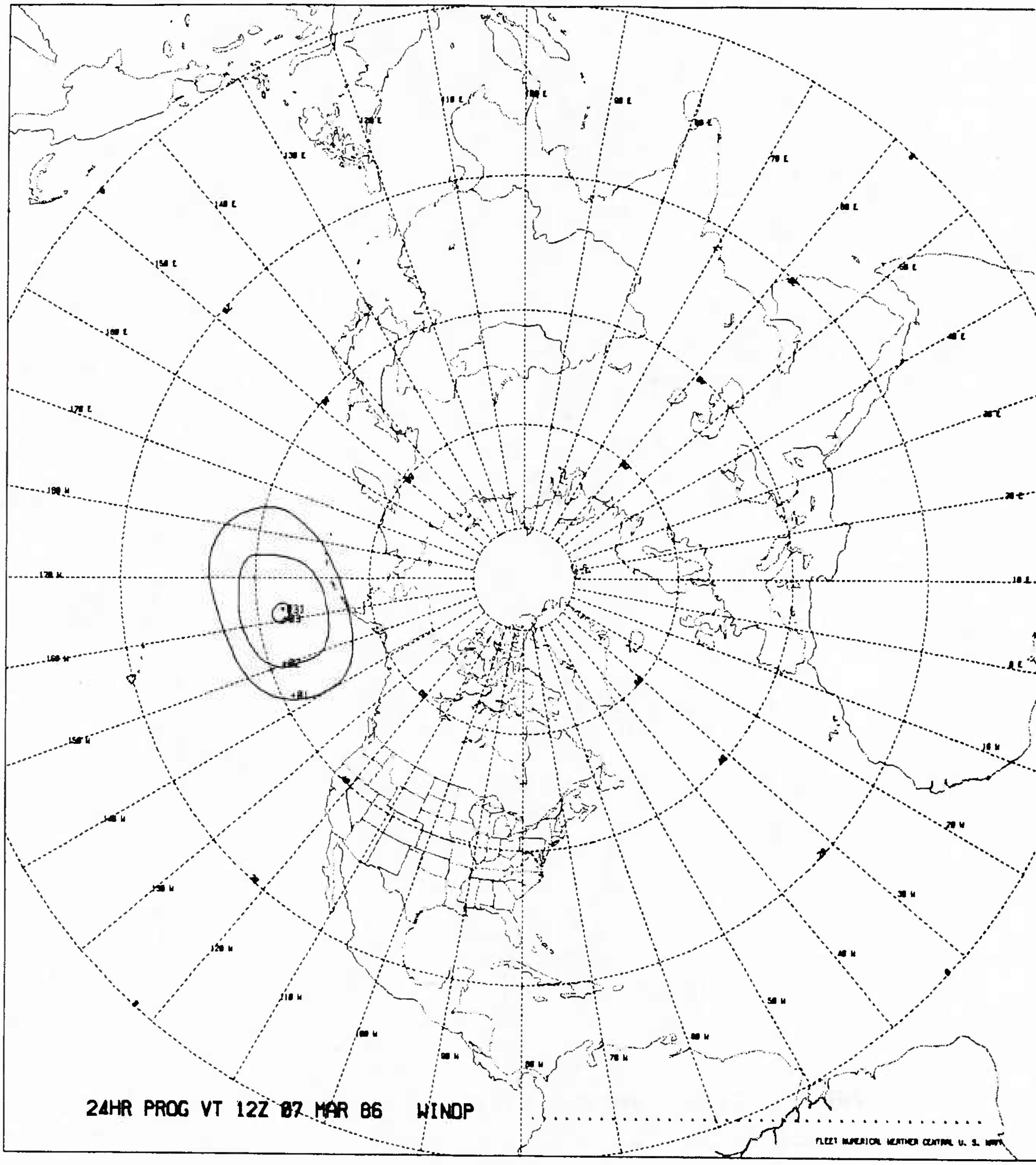

Figure 4. 24 Hour Gale Force Wind Probability for the Pacific.

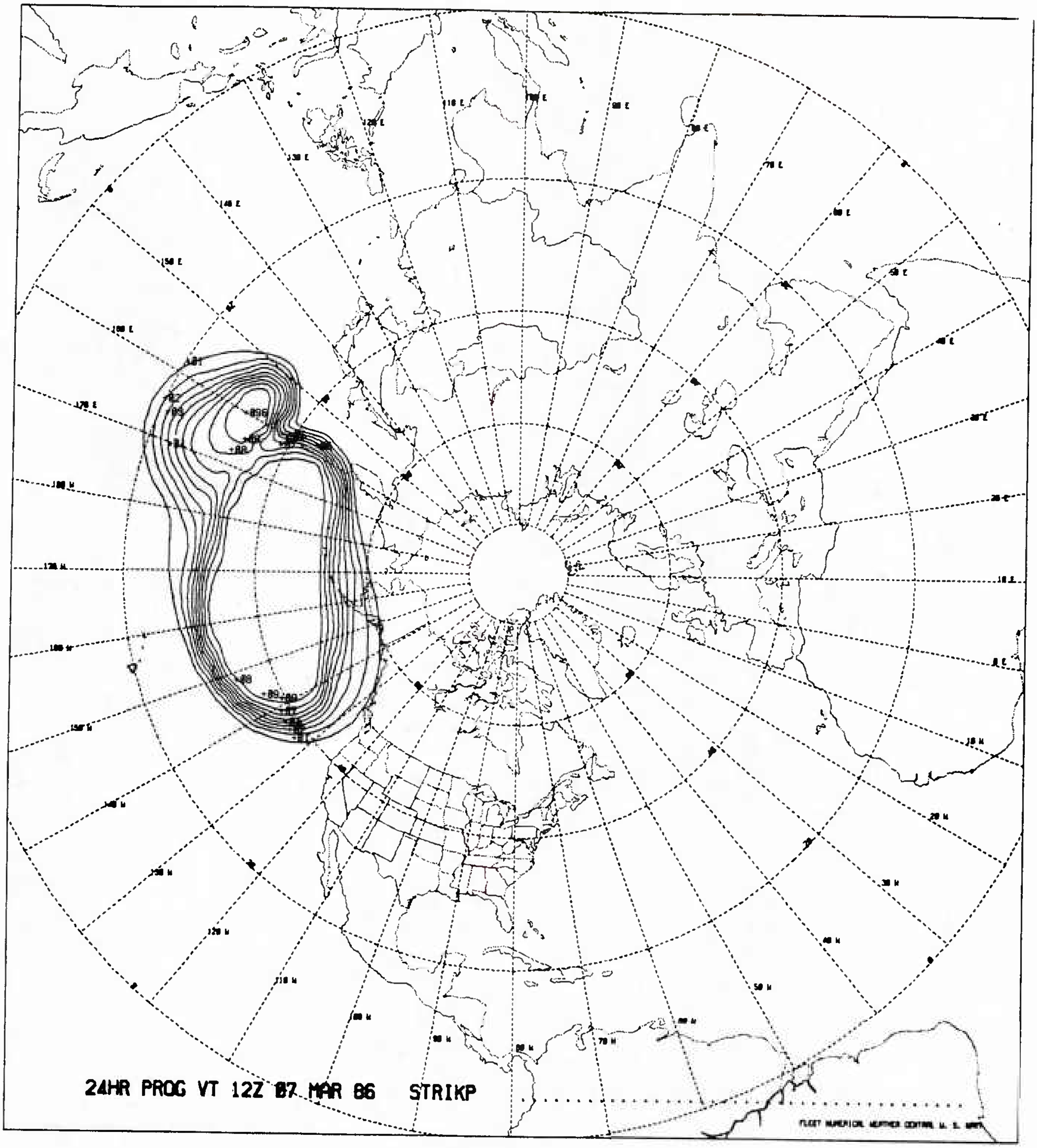

Figure 5. 24 Hour Elapsed Time Strike Probability for the Pacific.

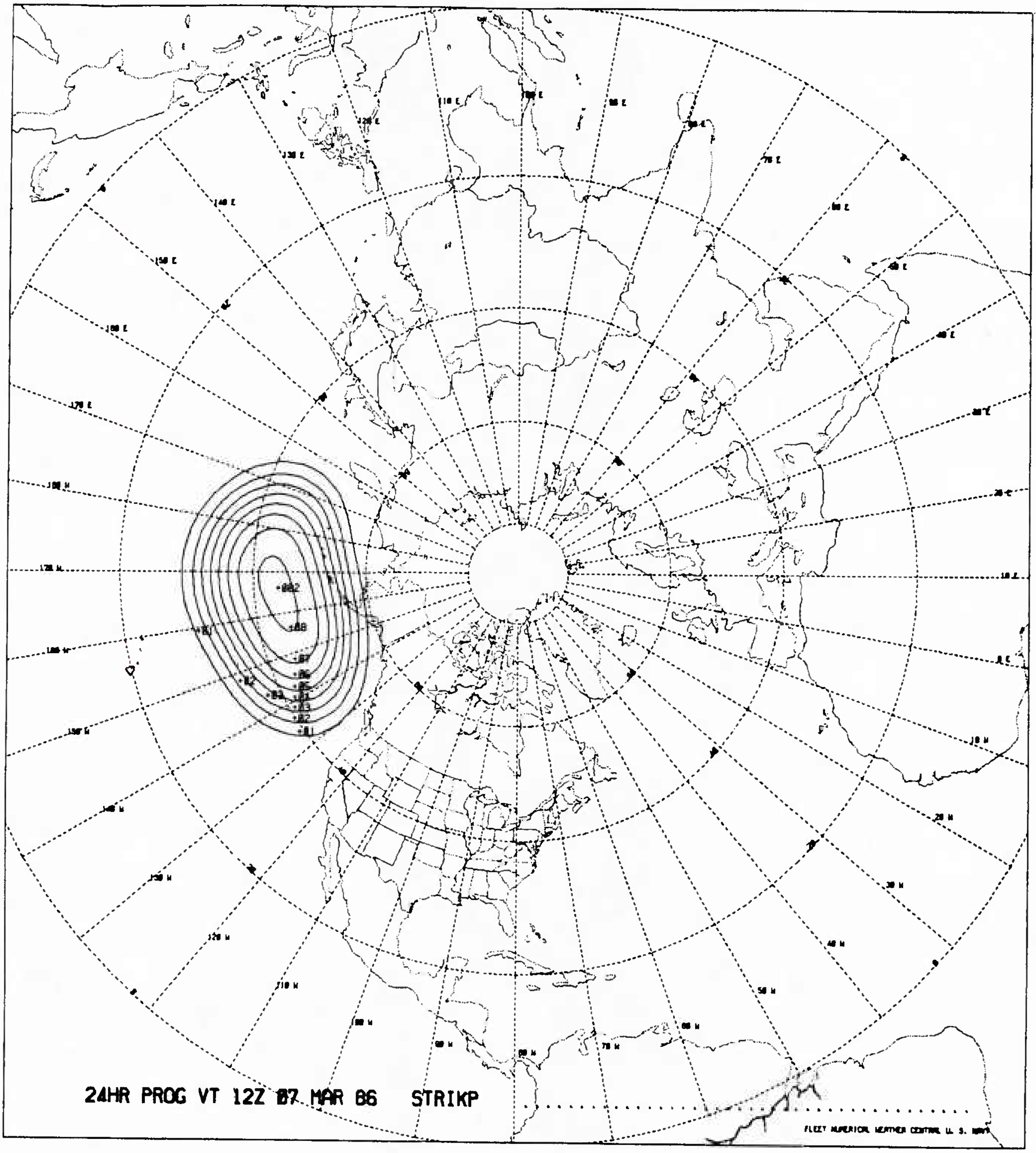

Figure 6. 24 Hour Strike Probability for the Pacific.

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